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Impact of Pretreatments on Quality of Dehydrated Jujube Fruits

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This study examined how different pretreatments and storage times affect the quality of dried jujube fruits, specifically exploring ascorbic acid retention, ash content, and color stability. Four different chemical pretreatments control (T_1), ethyl oleate (T_2), K_2CO_3 (T_3) and their combination (T_4) were used, and the fruits were stored for 180 days in zip-locked low-density polyethylene bags at room temperature. Key quality indicators, such as vitamin C, ash, and luminosity (L values), were regularly assessed. The findings showed that both storage duration and pretreatment significantly impacted the nutritional and visual quality of the fruits. Ascorbic acid levels declined across all treatments during storage, with T_2 revealing the best retention, while T_1 had the lowest levels. Ash content gradually increase, indicating concentration effects from moisture loss, with T_3 and T_4 showing the highest values, suggesting higher content. Likewise, L values (point out gloss) steadily declined, with T_2 retaining the highest luminosity, signifying less browning and improved color stability. The study concludes that T_2 is the most effective pretreatment for preserving both nutritional and sensory qualities, making it a beneficial approach for improving the quality and market appeal of dehydrated jujube fruits.

Keywords: Ascorbic acid, color change, shelf stability, dehydration, ethyl oleate, waxy cuticle, pretreatments.

INTRODUCTION

Jujube fruit is known as "live vitamin" or "king of vitamins (Niu *et al*., 2021)" as it is enriched with various nutrients with health promoting activities like heart protection, positive effect on stomach and anti-aging properties (Zhang *et al*., 2016). According to old Chinese fork saying, the significance of jujube fruit is highlighted by proverb "Eating three jujubes a day keeps the doctor away and keeps you young (Fu *et al*., 2021)". Fruits are typically consumed fresh as table fruit, but their ambient shelf life is extremely short, usually limited to ten days. However, fresh jujubes are highly perishable due to their high water and sugar content (Mao *et al*., 2024) resulting in fruit susceptibility to rot. Thus limited marketable period makes postharvest handling, long term supply, storage and processing of fresh jujubes almost impossible (Song *et al*., 2020; Wojdyło *et al*., 2019). In the Indo-Pak subcontinent, surplus jujube fruit during the glut season often leads to significant wastage and high postharvest losses (Anjum *et al*., 2020) often reach up to 15-30% in local markets (Liu *et al*., 2017). Therefore, water content of fresh jujube fruits must be decreased to 6% for prolonged storage (Moradinezhad and Dorostkar, 2021). Promotion of dehydration is thus necessary to ensure year-round supply of processed raw materials while retaining nutritional value and flavor. Drying is one of the most primitive and effective preservation technique in food industry (Zia and Alibas, 2021) demanding higher energy and time for reducing moisture to a safer limit to extend storability (Bao *et al*, 2021). Historically, sun drying was practiced for fresh produce dehydration; however, it is susceptible to adverse weather conditions, contamination risks, insect pest attacks, and prolonged drying times. Thick layer of waxy cuticle covers jujube fruit and serves as barrier for mechanical damage, fungal pathogens, maintains water and avoid leakage of nutrients. It also hinders water evaporation resulting in lengthy drying time on account of slow pace of drying and low moisture diffusivity. Removal of moisture from food substrate is the principle mechanism reducing water below safe limit and thus hinders microbial proliferation and enzymatic activity (Mao *et al*., 2024) while retaining valuable attributes of plant foods. Lower water activity reduces carriage costs, eases in processing and minimize chances of spoilage due to better quality (Moradinezhad and Dorostkar, 2021).

Drying impacts composition, appearance and vitamin C which is susceptible to thermal or oxidative degradation

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during processing (Wojdyło *et al*., 2019). Color is an imperative quality index of jujubes decisive to evaluate maturity, freshness, monitor and control quality changes during drying and storage as well as market value of dried fruits. Vitamin C is nutritional index, acts as an antioxidant. Treatments including non-chemical like heat shock, cold plasma, ultrasonic, blanching, superficial abrasion and chemicals like NaOH, KOH, K_2CO_3 and ethyl oleate were used in past studies to accelerate drying rate by dissolving cuticle (Bao *et al*, 2021). While various pretreatments have been explored, their comparative impact on specific quality attributes color stability and vitamin C retention of dehydrated jujubes over extended storage, especially for locally relevant varieties, remains underexplored. This study aims to investigate the impact of treatments on quality and shelf stability of dried jujube fruits.

MATERIALS AND METHODS

Fully ripe jujubes (*Zizyphus mauritiana* cv. Umran) were harvested from a local orchid, Faisalabad. Fruits of uniform shape, size and color were manually selected and washed with tap water to remove adhearing dust.

***Pretreatment of fruits*:** Jujubes were blanched at 90°C for 3 minutes and then dipped in ethyl oleate, potassium carbonate (K_2CO_3) and KMS solution before drying. Fruits were divided in four groups; control (blanched for 3 min and sulphiting 0.5% KMS for 10 minutes (T_1), 2% ethyl oleate dip for 2 minutes after blanching and sulphiting, 4% K_2CO_3 dip for 3 minutes after blanching and dip in ethyl oleate (1.5%) and K_2CO_3 (2.5%) solution for 3 minutes after blanching. Treated fruits were spread on shelf to drain any remaining liquid and air dried.

***Dehydration and storage*:** Dehydration of pretreated jujubes was conducted in hot air dryer at 50°C till constant weight. Dried jujubes > 9% moisture content were packed in polyethylene zip lock bags (LDPE 400 gauge) and stored at ambient conditions (Hoxha and Kongoli, 2020).

***Quality evaluation during storage*:** L, a* and b* color scores of dried fruit skin was measured using a colorimeter (CM-400d, Konica Minolta, Japan). The moisture percent was determined by placing weighed quantity of fruit at 70° C in a

Table 1. Moisture content of dehydrated jujube fruits.

Treat.	Storage days													Means
	0	15	30	45	60	75	90	105	120	135	150	165	180	
T1	9.45^{m-t}	9.51^{l-t}	9.58^{k-q}	9.65^{j-p}	9.71^{i-o}	9.87^{f-m}	9.96^{e-l}	10.06^{c-j}	10.11^{c-j}	10.26^{b-g}	10.27^{b-g}	10.48^{a-d}	10.63^{a-b}	9.96A
T2	8.92^{u}	9.09^{r-u}	9.18^{p-u}	9.29^{o-u}	9.39^{n-t}	9.44^{m-t}	9.55^{l-r}	9.73^{h-o}	9.74^{h-o}	9.85^{g-n}	10.05^{d-k}	10.08^{c-j}	10.25^{b-g}	9.58D
T3	9.05^{t-u}	9.07^{s-u}	9.18^{p-u}	9.37^{o-u}	9.44^{m-t}	9.67^{j-o}	9.87^{f-m}	9.94^{e-l}	10.2^{b-h}	10.38^{b-e}	10.49^{a-d}	10.63^{a-b}	10.87^{a}	9.86B
T4	9.12^{q-u}	9.08^{s-u}	9.17^{q-u}	9.31^{o-u}	9.37^{o-u}	9.54^{l-s}	9.73^{h-o}	9.75^{h-o}	9.93^{e-l}	10.08^{c-j}	10.15^{c-i}	10.33^{b-f}	10.53^{a-c}	9.70C
Means	9.13K	9.19K	9.28JK	9.41IJ	9.48HI	9.63GH	9.78FG	9.87EF	10.0DE	10.1CD	10.2BC	10.4AB	10.57A	9.78

Table 2. Ash content of dehydrated jujube fruits.

Treat.	Storage days													Means
	0	15	30	45	60	75	90	105	120	135	150	165	180	
T1	1.010^{q}	1.020^{p-q}	1.020^{p-q}	1.030^{m-q}	1.030^{m-q}	1.040^{m-q}	1.040^{m-q}	1.060^{k-o}	1.063^{j-n}	1.080^{i-l}	1.090^{h-k}	1.093^{g-k}	1.100^{f-j}	1.05C
T2	1.020^{p-q}	1.023^{o-q}	1.027^{n-q}	1.030^{m-q}	1.030^{m-q}	1.033^{m-q}	1.037^{m-q}	1.040^{m-q}	1.040^{m-q}	1.040^{m-q}	1.040^{m-q}	1.047^{l-p}	1.050^{l-p}	1.04D
T3	1.017^{p-q}	1.030^{m-q}	1.107^{e-i}	1.110^{e-i}	1.130^{c-g}	1.137^{b-f}	1.140^{a-e}	1.150^{a-d}	1.150^{a-d}	1.153^{a-d}	1.160^{a-c}	1.160^{a-c}	1.170^{a-b}	1.12A
T4	1.020^{p-q}	1.020^{p-q}	1.067^{j-m}	1.112^{e-i}	1.117^{d-i}	1.120^{d-h}	1.130^{c-g}	1.134^{c-g}	1.138^{b-f}	1.143^{a-e}	1.150^{a-d}	1.160^{a-c}	1.180^{a}	1.11B
Means	1.020H	1.020H	1.060G	1.070FG	1.077EF	1.083DEF	1.087DE	1.095CD	1.098CD	1.104BC	1.110ABC	1.115AB	1.124A	1.080

Table 3. TSS content of dehydrated jujube fruits.

Treat.	Storage days													Means
	0	15	30	45	60	75	90	105	120	135	150	165	180	
T1	69.80^{a-c}	69.38^{a-g}	68.03^{c-m}	67.46^{f-p}	67.21^{h-p}	66.91^{j-s}	66.73^{k-s}	66.37^{l-t}	65.07^{r-x}	64.38^{t-x}	64.05^{v-x}	63.46^{w-x}	63.04^{x}	66.30D
T2	70.24^{a-b}	69.66^{a-d}	69.54^{a-e}	69.05^{a-h}	68.70^{a-k}	68.29^{b-l}	68.06^{c-l}	67.90^{c-m}	67.60^{e-o}	67.24^{h-p}	66.95^{i-r}	66.73^{k-s}	66.57^{l-s}	68.20A
T3	69.51^{a-e}	68.98^{a-i}	68.94^{a-j}	67.91^{c-m}	67.69^{d-n}	67.45^{f-p}	67.29^{h-p}	66.98^{i-r}	66.88^{k-s}	66.02^{m-v}	65.49^{p-w}	65.14^{q-w}	64.33^{u-x}	67.12C
T4	70.65^{a}	69.59^{a-e}	69.47^{a-f}	68.62^{a-k}	68.18^{c-l}	67.91^{c-m}	67.37^{g-p}	67.14^{h-q}	66.54^{l-s}	66.31^{l-u}	65.83^{n-v}	65.58^{o-v}	64.88^{s-x}	67.54B
Means	70.05A	69.40AB	68.99BC	68.26CD	67.94DE	67.64DEF	67.36EF	67.10FG	66.52GH	65.99HI	65.58I	65.23IJ	64.71J	67.29

Table 4. L color values of dehydrated jujube fruits.

Treat.	Storage days													Means
	0	15	30	45	60	75	90	105	120	135	150	165	180	
T1	52.58^{h-o}	52.20^{j-r}	52.11^{j-s}	52.03^{k-s}	51.50^{n-t}	51.19^{p-t}	50.89^{s-u}	50.43^{t-v}	49.85^{u-w}	49.2^{v-x}	48.72^{w-y}	48.31^{x-y}	47.82^{y}	50.53D
T2	54.71^{a}	54.63^{a}	54.57^{a-b}	54.51^{a-c}	54.47^{a-d}	54.41^{a-d}	54.35^{a-d}	54.29^{a-e}	54.15^{a-f}	53.56^{a-h}	53.03^{e-l}	52.39^{h-p}	52.13^{j-s}	53.94A
T3	54.18^{a-f}	54.11^{a-f}	53.94^{a-g}	53.64^{a-h}	53.49^{a-i}	53.35^{b-j}	53.23^{d-k}	52.73^{g-n}	52.26^{i-q}	51.86^{l-s}	51.38^{o-t}	51.08^{q-u}	50.44^{t-v}	52.75B
T4	53.26^{c-k}	53.03^{e-l}	52.92^{f-l}	52.82^{g-m}	52.63^{h-o}	52.37^{h-p}	52.06^{k-s}	51.85^{l-s}	51.59^{m-t}	51.26^{p-t}	51.05^{q-u}	50.93^{r-u}	50.57^{t-u}	52.03C
Means	53.68A	53.49AB	53.39AB	53.3ABC	53.0BCD	52.8CDE	52.63DE	52.33EF	51.96FG	51.47GH	51.05HI	50.68IJ	50.24J	52.31

hot air drying oven until the constant weight. Ash content was determined in muffle furnace at 650C till constant weight. The result were reported as g/100 g weight of sample. Total soluble solids were recorded as ºBrix using digital refractometer. Acid content was measured by titration with 0.1 N NaOH and results reported as g citric acid/100 g. The quantity of vitamin C in dried jujubes was measured using detective dye 2, 6-dichlorophenol indophenol (Hoxha and Kongoli, 2020).

***Statistical analysis*:** The experiment was conducted in factorial arrangements under CRD and data was analyzed using ANOVA technique and post hoc means were compared using Tucky HSD test at α=5%.

RESULTS AND DISCUSSION

***Moisture content*:** Moisture content in dry jujubes rose over 180 days with T_1 recording the highest increase (9.45 to 10.63%) and the lowest (8.92 to 10.25%) in T_2 (Table 1). The mean moisture content increased from 9.13 (day 0) to 10.57% (day 180). T_2 was the best treatment in moisture control, and T_1 accumulated the maximum moisture with possible effects on quality and shelf life. This rise could be due to absorption of moisture during storage. Storage conditions and treatment (T_2) effectively prevented reabsorption of moisture (Anjum *et al*., 2020).

***Ash content*:** Ash content in dry jujube fruits rose during storage for more than 180 days, indicating the concentration of minerals as a result of water loss. T_3 always recorded the highest ash content, followed by T_4, whereas T_1 and T_2 recorded lower values (Table 2). The lowest ash content (1.04%) was found in T_2, and the highest (1.12%) in T_3. Generally, ash content increased from 1.02 at day 0 to 1.12% at day 180. This is an indication of mineral retention, with T_3 and T_4 having higher efficiency in maintaining mineral stability, while T_1 and T_2 had lower retention efficiency (Hoxha and Kongoli, 2021).

Total soluble solids: Pretreatments and storage time had a significant impact on the total solid content (TSS) of dried jujubes. T_2 always had the highest TSS (68.20 °B), followed by T_4 (67.54°B), T_3 (67.12°B), and T_1 (66.30°B). TSS reduced steadily from 70.05°B (Day 0) to 64.71°B (Day 180) in all the treatments, where T_1 registered the minimum TSS on Day 180 (Table 3). The decline in TSS can be attributed to moisture absorption during storage (Yaşa *et al*., 2023). These observations are in consonance with the earlier research where TSS fell slightly when stored (Hoxha and Kongoli, 2021; Yaşa *et al*., 2023).

***Color values*:** The luminosity (L) value of dried jujubes declined during 180 days storage, indicating darkening due to non-enzymatic browning, polyphenol oxidation, water loss, and pigment instability. T_2 (ethyl oleate treatment) retained the highest L values (54.71 to 52.13), showing better color stability and gloss, while T_1 had the lowest values (52.58 to 47.82) (Table 4), indicating the greatest degradation. Overall, L values declined from 53.68 (day 0) to 50.24 (day 180), with a notable decline after 60 days. T_2 was the most effective treatment for retaining luminosity. The darkening of jujubes over time is attributed to oxidation, moisture loss, and Maillard reactions during dehydration (Cao *et al*., 2018; Xu *et al*., 2023). The graph indicates how critical pretreatments are to sustaining red color (positive a* values) of dried jujubes in storage. The a* values rise over time, representing darkening, with T_1 registering the largest a* values (more darkening) and T_2 best at sustaining color with least change (Fig. 1a). On day 180, T_2 exhibited least change in a*, thereby being the most efficient treatment in preserving red color. The decrease in the values of a* over time indicates the effect of storage duration on color. It was determined in previous research that drying increased redness in jujubes because of green component degradation and red pigment formation (Cao *et al*., 2018; Hoxha and Kongoli, 2020).

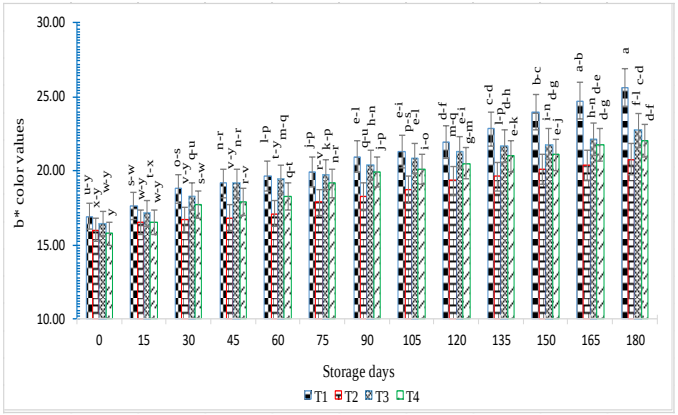

Figure 1a. a* color scores of dried jujubes.

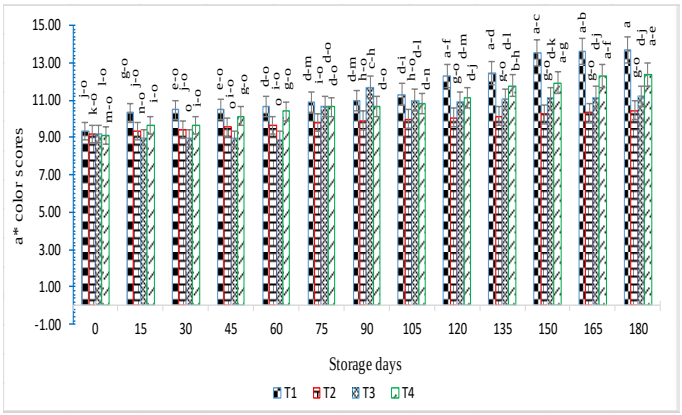

Figure 1b. b* color scores of dried jujubes.

The graph illustrates the significance of pretreatments on retaining b* color values, influencing the quality and acceptability of dried jujubes. B* values increased over

time, signaling movement towards yellow. T_2 always maintained the lowest b* values signaling movement towards yellow, having better color retention than other treatments, whereas T_1 exhibited higher b* value depicting lower retention (Fig. 1b). On day 180, T_2 was best at maintaining color stability. This rise in b* values indicates a color drift in the natural direction while in storage, which is affected by pretreatment, drying and storage conditions (Cao *et al*., 2018; Hoxha and Kongoli, 2020).

***Vitamin C*:** Pretreatments, storage period, and interactions also played an important role in influencing the content of ascorbic acid in dehydrated jujube fruits for 180 days. At the start, all the treatments exhibited similar vitamin C level, but distinctions were more noticeable with time of storage. T_2 had possessed the greatest quantity of retained vitamin C, while maximum reduction in T_1. At day 180, T_2 recorded the highest retention of vitamin C, testifying to its preservative ability, and T_1 had the least (Fig. 2a). This reduction is due to heat degradation, oxidation, and enzymatic action during drying and storage (Niu *et al*., 2021). The same pattern of vitamin C loss was reported in earlier research (Hoxha and Kongoli, 2021).

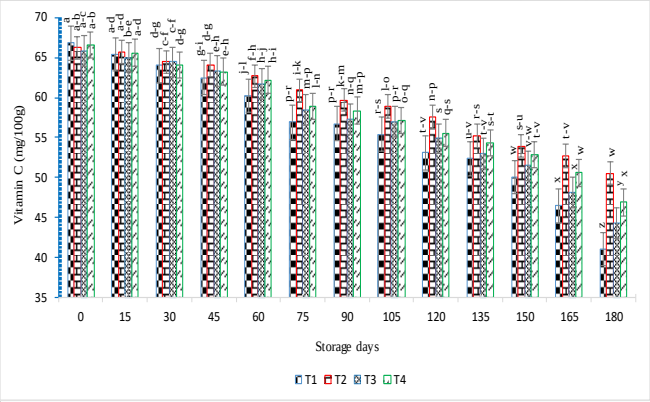

Figure 2a. Vitamin C content of dried jujubes

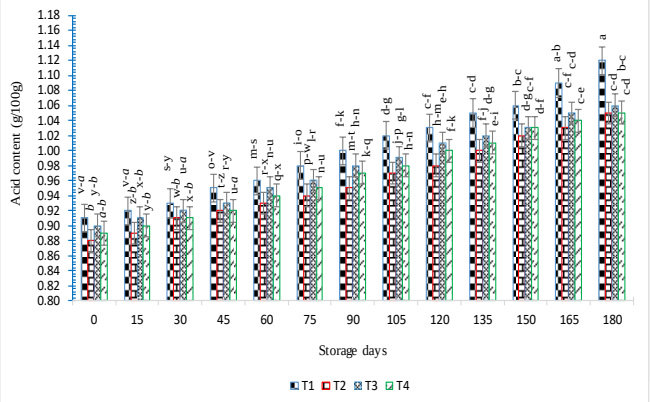

Figure 2b. Acid content of dried jujubes.

Acid content: Acid content was similar among treatments at Day 0, with the highest in T_1 and the lowest in T_4. During storage acid gradually rose across all treatments due to suspected biochemical or microbial activity. The variations widened with the progress of storage, and T_1 having notably increased acid content by Day 180 (Fig. 2b). The accumulation of acid over a period of time is due to metabolic activities or fermentation (Hoxha and Kongoli, 2021; Yaşa *et al*., 2023) and consist with earlier studies on acid buildup in dry jujubes (Arsalan *et al*., 2021).

***Conclusion*:** This study emphasized the need to optimize drying conditions to enhance the quality of jujubes. The balance of temperature and time improves drying efficiency without losing nutrients and sensory attributes. Pretreatment and storage conditions greatly affect the nutritional and sensory quality of dehydrated jujubes. T_2 performed better in Vitamin C retention compared to other treatments, while T_3 and T_4 exhibited improved mineral stability. T_2 also retained color brightness, which retained the fruits' visual quality. The results emphasize the need to choose appropriate pretreatments for enhancing shelf life and consumer acceptability. Future studies may investigate new drying technologies and natural antioxidants to further increase quality and stability.

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***Conflict of interest*:** The authors declare no conflict of interest

***Ethical statement*:** This article dose not contains any study related to humans or animals.

***Availability of data*:** The data will be available on request

***Consent to participate*:** All authors participated in this research study.

***Informed consent*:** The participants signed informed consent regarding publishing their data.

***Consent for publication*:** All authors submitted consent to publish this research article in JGIAS

***SDGs addressed*:** No poverty; Zero hunger; good health and well-being.

***Policy referred*:** Indonesia's National Policy on Food and Nutrition, Indonesian Food Security and Nutrition Roadmap

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